CONTROL VALVE FOR VARIABLE DISPLACEMENT COMPRESSOR

Cross-References to Related Applications, If Any:

This application claims priority of Japanese Applications No.2002-308576 filed on October 23, 2002, entitled "Control Valve for Variable Displacement Compressor", No.2003-048392 filed on February 26, 2003, entitled "Control Valve for Variable Displacement Compressor" and No.2003-289581 filed on August 8, 2003, entitled "Control Valve for Variable Displacement Compressor".

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a control valve for a variable displacement compressor, and more particularly to a control valve employed in a variable displacement compressor of an automotive air conditioner, for controlling the refrigerant discharge capacity.

(2) Description of the Related Art

A compressor used in a refrigeration cycle of an automotive air conditioner is driven by an engine whose rotational speed is varied depending on a traveling condition of the vehicle, and hence is incapable of performing rotational speed control. For this reason, in general, a variable displacement compressor capable of

changing the refrigerant discharge capacity is employed so as to obtain an adequate refrigerating capacity without being constrained by the rotational speed of the engine.

In the variable displacement compressor, in general, a wobble plate disposed within a crank chamber formed gastight, such that the inclination angle thereof can be changed, is driven by the rotational motion of a rotational shaft, for performing wobbling motion, and pistons caused to perform reciprocating motion in a direction parallel to the rotational shaft by the wobbling motion of the wobble plate draw refrigerant from a suction chamber into associated cylinders, compress the refrigerant, and then discharge the same into a discharge chamber. In doing this, the inclination angle of the wobble plate is varied by changing the pressure in the crank chamber, whereby the refrigerant discharge capacity is varied. The control valve for a variable displacement compressor provides control to change the pressure in the crank chamber.

In general, such a control valve for a variable displacement compressor, which variably controls the discharge capacity of the compressor, operates to introduce part of refrigerant discharged from the discharge chamber and having discharge pressure Pd into the crank chamber formed gastight, such that pressure Pc in the crank chamber is controlled through control of the amount of refrigerant thus introduced, which control is

carried out according to suction pressure Ps in the suction chamber. That is, the control valve for a variable displacement compressor senses the suction pressure Ps, and controls the flow rate of refrigerant introduced from the discharge chamber into the crank chamber at the discharge pressure Pd, so as to hold the suction pressure Ps at a constant level.

To this end, the control valve for a variable displacement compressor is equipped with a pressure-sensing section for sensing the suction pressure Ps, and a valve section for causing a passage leading from the suction chamber to the crank chamber to open and close according to the suction pressure Ps sensed by the pressure-sensing section. Further, a type of the control valve for a variable displacement compressor which is capable of freely externally setting a value of suction pressure Ps to be assumed, at the start of the variable placement operation, is equipped with a solenoid that enables configuration of settings of the pressure-sensing section by external electric current.

By the way, conventional control valves for a variable displacement compressor which can be externally controlled include a type for control of a variable displacement compressor configured such that an engine is directly connected to a rotational shaft of the compressor without providing an electromagnetic clutch between the engine and the rotational shaft on which a wobble plate is

fitted, for execution and inhibition of transmission of a driving force of the engine (see e.g. Japanese Unexamined Patent Publication No. 2000-110731 (Paragraph Nos. [0010] and [0044], and FIG. 1)).

This control valve comprises a valve section causing a passage communicating between a discharge chamber and a crank chamber to be opened and closed, a solenoid for generating an electromagnetic force causing the valve section to operate in the closing direction, and a pressure-sensing section for causing the valve section to operate in the opening direction as suction pressure Ps becomes lower compared with the atmospheric pressure, which are arranged in this order. Therefore, when the solenoid is not energized, the valve section is in a fully open state, whereby pressure Pc in a crank chamber can be held at a pressure close to discharge pressure Pd. This causes the wobble plate to become substantially at right angles to the rotational shaft, enabling the variable displacement compressor to operate with minimum capacity. Thus, the refrigerant discharge capacity can be substantially reduced to approximately zero even when the engine is directly connected to the rotational shaft, which makes it possible to eliminate the electromagnetic clutch.

However, the conventional control valve for controlling a variable displacement compressor dispensed with the electromagnetic clutch is configured such that

the pressure-sensing section and the valve section are arranged with the solenoid interposed therebetween, and the suction pressure Ps is introduced to the pressure-sensing section which compares the suction pressure Ps and the atmospheric pressure, via the solenoid. This necessitates the solenoid in its entirety to be accommodated within a pressure chamber, and hence components of the solenoid need to be designed with considerations given to resistance to pressure.

SUMMARY OF THE INVENTION

The present invention has been made in view of these points, and an object thereof is to provide a control valve for a variable displacement compressor, which is capable of controlling the variable displacement compressor to the minimum capacity without using an electromagnetic clutch, and can be constructed without accommodating a solenoid in a pressure chamber.

To solve the above problem, the present invention provides a control valve for a variable displacement compressor for controlling pressure in a crank chamber formed gastight to thereby change a refrigerant discharge capacity, characterized in that a plunger of a solenoid is divided into a first plunger and a second plunger, and a pressure-sensing member is disposed between the first plunger and the second plunger, for sensing suction pressure in a suction chamber.

The above and other objects, features and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a first embodiment.

FIG. 2 is a central longitudinal cross-sectional view showing the control valve for a variable displacement compressor in a state where the variable displacement compressor is started.

FIG. 3 is a central longitudinal cross-sectional view showing the control valve for a variable displacement compressor in a state where the variable displacement compressor is in steady operation.

FIG. 4 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a second embodiment.

FIG. 5 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a third embodiment.

FIG. 6 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a fourth embodiment.

FIG. 7 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a fifth embodiment.

FIG. 8 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a sixth embodiment.

FIG. 9 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a seventh embodiment.

FIG. 10 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to an eighth embodiment.

FIG. 11 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a ninth embodiment.

FIG. 12 is a partial enlarged central longitudinal cross-sectional view for explaining a valve section of a control valve for a variable displacement compressor,

according to a tenth embodiment.

FIG. 13 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to an eleventh embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

FIG. 1 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a first embodiment of the invention.

The control valve for the variable displacement compressor includes a valve section in an upper location as viewed in the figure. In the valve section, an opening in the top of a body 11 forms a port 12 which communicates with a discharge chamber of the variable displacement compressor and receives discharge pressure Pd, and a strainer 13 is provided on the port 12. The port 12 receiving the discharge pressure Pd internally communicates with a port 14 communicating with a crank chamber of the variable displacement compressor and formed in the body 11 so as to guide controlled pressure Pc out into the crank chamber, and a valve seat 15 is formed in a refrigerant passage communicating between the port 12 and the port 14, as an integral part of the body 11. In

opposed relation to a side of the valve seat where the discharge pressure Pd is received, a valve element 16 is disposed in an axially movable manner. The valve element 16 is urged in the valve-closing direction by a spring 17 which has its load adjusted by an adjustment screw 18 screwed into the port 12. Below the body 11, as viewed in the figure, there is formed a port 19 communicating with a suction chamber of the variable displacement compressor and receiving suction pressure Ps.

A hollow cylindrical member 20 is disposed at a lower end of the body 11, and a first plunger 21 is axially movably disposed within the hollow cylindrical member 20. The first plunger 21 has a guide 22, which is made e.g. of polytetrafluoroethylene and has a low sliding resistance, fitted along the periphery thereof at a lower part location as viewed in the figure. The outer peripheral surface of the guide 22 is in sliding contact with the inner wall of the hollow cylindrical member 20, whereby when the first plunger 21 axially moves, the guide 22 serves to guide the first plunger 21, while maintaining the same at a predetermined distance from the inner wall of the hollow cylindrical member 20. It should be noted that the guide 22 is not provided along the entire circumference of the first plunger 21, but has one portion thereof cut open, thereby allowing the suction pressure Ps to be introduced into a space formed on a lower end side of the first plunger 21.

The first plunger 21 has a flange 23 fixed to an upper end location thereof by press-fitting, with a spring 24 interposed between the flange 23 and an upper end face of the hollow cylindrical member 20. A shaft 25, which is axially movably disposed within the body 11 with almost no clearance between the same and the body 11, has a lower end thereof fixed to the first plunger 21, by press-fitting, at an upper axial location of the first plunger 21. Thus, the shaft 25 and the guide 22 position the first plunger 21 on the axis of the body 11. The upper end of the shaft 25 extends through a valve hole and is in contact with the valve element 16.

The spring 24 urging the first plunger 21 upward as viewed in the figure is configured to have a larger spring force than that of the spring 17 urging the valve element 16 in the valve-closing direction. Therefore, when the solenoid is not energized, the first plunger 21 is in abutment with the ceiling of a chamber communicating with the port 19, and the valve element 16 with which the shaft 25 is in contact is in its fully open position.

Below the first plunger 21, a diaphragm 26 constituting a pressure-sensing section is disposed. The diaphragm 26 has its outer peripheral edge sandwiched by the hollow cylindrical member 20 and a casing 27 of the solenoid, and sealed by a gasket 28. The sandwiching of the diaphragm 26 by the hollow cylindrical member 20 and the casing 27 of the solenoid is realized by swaging an

upper end edge of the casing 27 as viewed in the figure onto the lower end of the body 11 as viewed in the figure, with the hollow cylindrical member 20 held therebetween. Thus, part forming a pressure chamber of the control valve for the variable displacement compressor extends up to a portion partitioned by the diaphragm 26, and part lower than this portion receives the atmospheric pressure. It should be noted that the diaphragm 26 is formed e.g. of one piece of polyimide film. However, by using a plurality of pieces thereof overlaid one upon other as required, it is possible to increase resistance to breakage which might be caused by repeated collision of the first plunger 21.

Within the casing 27, a magnet coil 29 is disposed, and inside the magnet coil 29 is disposed a sleeve 30. The sleeve 30 has a core 31 inserted into a lower portion thereof and fixed thereto. Between the core 31 and the diaphragm 26 is disposed a second plunger 32 such that the second plunger 32 is axially movable within the sleeve 30. The second plunger 32 has the upper end of a shaft 33 disposed along the axis thereof, as viewed in the figure, fixed thereto by press-fitting, with the lower end of the shaft 33 being supported by a bearing 35 disposed within a knob 34 which closes the open end of the casing 27. Disposed between the second plunger 32 and the core 31 is a spring 36 which urges the second plunger 32 toward the diaphragm 26.

The body 11 has an O ring 37 fitted on a periphery

thereof at a location between the port 12 via which the discharge pressure Pd is introduced and the port 14 via which the pressure Pc is guided out into the crank chamber, and has an O ring 38 fitted on a periphery thereof at a location between the port 14 via which the pressure Pc is guided out and the port 19 via which the suction pressure Ps is introduced. The lower end of the casing 27 as viewed in the figure has an O ring 39 fitted on a periphery thereof for cutting off the suction pressure Ps from the atmospheric pressure. Further, the magnet coil 29 is supplied with control current via a harness 40.

In the above construction described above, the hollow cylindrical member 20, the casing 27, and the knob 34 are made of magnetic materials, thereby serving as a yoke of a magnetic circuit of the solenoid, with the lines of magnetic force generated by the magnet coil 29 extending through the magnetic circuit formed by the casing 27, the hollow cylindrical member 20, the first plunger 21, the second plunger 32, the core 31, and the knob 34.

The control valve for a variable displacement compressor as shown in the figure is in a state wherein the solenoid is not energized, and the suction pressure Ps is high, that is, when the air conditioner is not in operation. Since the suction pressure Ps is high, the diaphragm 26 is displaced downward, as viewed in the figure, against the load of the spring 36 to thereby bring

the second plunger 32 into abutment with the core 31. On the other hand, the first plunger 21 is urged upward as viewed in the figure by the spring 24, so that it is moved away from the diaphragm 26, and hence in a state free from influence of the diaphragm 26 which is displaced by changes in the suction pressure Ps. Further, the first plunger 21 urges the valve element 16 toward the fully open position thereof via the shaft 25. Therefore, in this state, even when the rotational shaft of the variable displacement compressor is driven for rotation by the engine, the variable displacement compressor is operated with the minimum discharge capacity.

FIG. 2 is a central longitudinal cross-sectional view showing the control valve for a variable displacement compressor in a state where the variable displacement compressor is started, and FIG. 3 is a central longitudinal cross-sectional view showing the control valve for a variable displacement compressor in a state where the variable displacement compressor is in steady operation.

When the maximum control current is supplied to the magnet coil 29 of the solenoid, as in the case of the variable displacement compressor having been started, as shown in FIG. 2, the second plunger 32 is pressed downward as viewed in the figure by the high suction pressure Ps to be brought into abutment with the core 31, so that even if the second plunger 32 is attracted by the core 31, it

remains in the same position. Therefore, in this case, the second plunger 32 and the core 31 behaves as if they were a fixed core, so that the second plunger 32 attracts the first plunger 21, causing the first plunger 21 to be attached to the second plunger 32 via the diaphragm 26, whereby the shaft 25 is pulled downward. As a result, the spring 17 causes the valve element 16 to be seated on the valve seat 15, to fully close the valve section. This blocks off the passage extending from the discharge chamber to the crank chamber, so that the variable displacement compressor is promptly shifted into the operation with the maximum capacity.

When the variable displacement compressor continues to operate with the maximum capacity to make the suction pressure Ps low enough, the diaphragm 26 senses the suction pressure Ps to attempt to move upward as viewed in the figure. At this time, if the control current supplied to the magnet coil 29 is decreased according to the set temperature of the air conditioner, as shown in FIG. 3, the first plunger 21, the diaphragm 26, and the second plunger 32 in attracted state move in unison upward as viewed in the figure to a position where the suction pressure Ps, the loads of the springs 17, 24, and 36, and the attractive force of the solenoid are balanced. This causes the valve element 16 to be pushed upward as viewed in the figure by the shaft 25 to move away the valve seat 15, to be set to a predetermined valve lift. Therefore,

refrigerant having discharge pressure Pd is introduced into the crank chamber at a flow rate controlled to a value dependent on the valve lift, whereby the variable displacement compressor is shifted to operation with the capacity corresponding to the control current.

When the control current supplied to the magnet coil 29 of the solenoid is constant, the diaphragm 26 senses the suction pressure Ps to thereby control the valve lift of the valve section. For example, when the refrigerating load is increased to make the suction pressure Ps high, the diaphragm 26 is displaced downward as viewed in the figure, so that the valve element 16 is also moved downward to decrease the valve lift of the valve section, causing the variable displacement compressor to operate in a direction of increasing the discharge capacity. On the other hand, when the refrigerating load is decreased to make the suction pressure Ps low, the diaphragm 26 is displaced upward as viewed in the figure to increase the valve lift of the valve section, causing the variable displacement compressor to operate in a direction of decreasing the discharge capacity. Thus, the variable displacement compressor operates to make the suction pressure Ps constant.

FIG. 4 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a second embodiment of the present invention, and component

elements identical or equivalent to those shown in FIG. 1 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to the second embodiment is distinguished from the control valve according to the first embodiment in that the locations of the port 12 receiving discharge pressure Pd from the discharge chamber and the port 14 from which the controlled pressure Pc is guided out into the crank chamber are inverted.

In the control valve for a variable displacement compressor, the valve element 16 is integrally formed with a pressure-sensing piston 41, and the discharge pressure Pd is introduced into a reduced-diameter portion connecting the valve element 16 and the pressure-sensing piston 41. The pressure-sensing piston 41 has an outer diameter equal to an inner diameter of a valve hole forming the valve seat 15, whereby the pressure-receiving area of the valve element 16 and the pressure-receiving area of the pressure-sensing piston 41 are made equal to each other. This causes the force of the discharge pressure Pd acting to move the valve element 16 upward as viewed in the figure to be cancelled out by the force of the same acting to move the pressure-sensing piston 41 downward as viewed in the figure, thereby enabling the solenoid and the diaphragm 26 to control the valve element 16 without being influenced by the discharge pressure Pd

which is high.

The pressure-sensing piston 41 has a function of canceling out influence of the discharge pressure Pd and a function of a shaft for transmitting the motions of the solenoid and the diaphragm 26 to the valve element 16, as in the case of the control valve for a variable displacement compressor, according to the first embodiment.

The other features of the construction in which the plunger is divided into two with the diaphragm 26 disposed therebetween and the construction of the solenoid are the same as those of the control valve for a variable displacement compressor, according to the first embodiment, and hence description of the operation thereof is omitted.

FIG. 5 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a third embodiment of the present invention, and component elements identical or equivalent to those shown in FIG. 1 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to the third embodiment is distinguished from the control valves according to the first embodiment and the second embodiment in that the control valve performs the control of the flow rate of refrigerant having pressure Pc allowed to escape from the crank chamber to the suction chamber in addition to the

control of the flow rate of refrigerant having discharge pressure Pd introduced into the crank chamber, which is carried out by the control valves according to the first and second embodiments.

In this control valve for a variable displacement compressor, the passage communicating with the crank chamber is divided in two. That is, the body 11 has a port 14a via which controlled pressure Pc1 is guided out into the crank chamber and a port 14b via which pressure Pc2 is introduced from the crank chamber. This is for forming a passage allowing refrigerant introduced from the discharge chamber and controlled by the valve section to once enter the crank chamber and then flow from the crank chamber into the suction chamber, so as to cause lubricating oil mixed in the refrigerant for lubrication of the compressor, to be positively flow by way of the crank chamber.

The port 14b via which the refrigerant returns from the crank chamber opens, via a communication passage 42, into space communicating with the port 19 leading to the suction chamber. The opening which opens into the space is configured to be opened and closed by the first plunger 21. Therefore, when the valve section is fully closed, a passage between the crank chamber and the suction chamber is opened, to maximize the flow rate of refrigerant allowed to flow from the crank chamber to the suction chamber, thereby enabling the compressor to perform prompt transition to the maximum capacity operation, while the

valve section is fully open, the passage between the crank chamber and the suction chamber is closed, to maximize the flow rate of refrigerant introduced from the discharge chamber into the crank chamber, thereby enabling the compressor to perform prompt transition to the minimum capacity operation.

The other features of the construction in which the plunger is divided into the first plunger 21 and the second plunger 32 with the diaphragm 26 disposed therebetween, and the construction of the solenoid are the same as those of the control valve for a variable displacement compressor, according to the first embodiment. Therefore, the operation of this control valve for a variable displacement compressor is the same as that of the control valve for a variable displacement compressor, according to the first embodiment, and hence description thereof is omitted.

FIG. 6 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a fourth embodiment of the present invention. In FIG. 6, component elements identical or equivalent to those shown in FIG. 1 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to the fourth embodiment includes cushioning means for softening impact of collision of the

first plunger 21 with the diaphragm 26 occurring when the first plunger 21 is attracted to the second plunger 32 upon energization of the solenoid. More specifically, a disk 43 is interposed between the first plunger 21 and the diaphragm 26, and a spring 44 is interposed between the first plunger 21 and the disk 43. This arrangement has not only the function of constantly bringing the disk 43 into contact with the diaphragm 26, but also the same function as the function of the spring 24 urging the first plunger 21 toward the valve section as in the case of the control valves for a variable displacement compressor, according to the first to third embodiments. The disk 43 is held by a guide 22 formed on the outer periphery of the first plunger 21 and extending further downward with respect to a lower end of the first plunger 21.

With the above arrangement, the disk 43 is urged by the spring 44, so that the second plunger 32, the diaphragm 26, and the disk 43 are always in contact with each other, and move in unison. When the solenoid is not energized, as shown in the figure, the first plunger 21 and the disk 43 are made separate from each other by the spring 44. When the solenoid is energized, the first plunger 21 is attracted by the disk 43 integrated therewith and attached to the disk 43 by collision. The force of impact of the collision is transmitted to the diaphragm 26 after being absorbed for cushioning by the disk 43, so that the impact on the diaphragm 26 is reduced.

The other features of the construction in which the plunger is divided into the first plunger 21 and the second plunger 32 with the diaphragm 26 disposed therebetween, and the construction of the solenoid are also the same as those of the control valve for a variable displacement compressor, according to the first embodiment. Therefore, the operation of this control valve for a variable displacement compressor is the same as that of the control valve for a variable displacement compressor, according to the first embodiment, and therefore description thereof is omitted.

FIG. 7 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a fifth embodiment of the present invention. In FIG. 7, component elements identical or equivalent to those shown in FIG. 4 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to the fifth embodiment includes a mechanism for adjusting the load of the spring 36, in addition to the construction of the control valve for a variable displacement compressor, according to the second embodiment. More specifically, an adjustment screw 45 is screwed into the knob 34 at the lower end of the valve as viewed in the figure, and the adjustment screw 45 is formed to have such a shape that it supports the lower end

of the shaft 33 in an axially movable manner. A retaining ring 46 is fitted on an intermediate portion of the shaft 33, and a spring retainer 47 is provided such that the upward motion, as viewed in the figure, of the spring retainer 47 is limited by the retaining ring 46. A spring 36 is interposed between the spring retainer 47 and the adjustment screw 45. With this arrangement, the amount of screw-in of the adjustment screw 45 into the knob 34 can be adjusted to adjust the load of the spring 36, thereby adjusting the set value for the control valve for a variable displacement compressor.

FIG. 8 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a sixth embodiment of the present invention. In FIG. 8, component elements identical or equivalent to those shown in FIGS. 6 and 7 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to a sixth embodiment of the present invention is configured such that the first plunger 21 and the disk 43 are axially movably guided by a sleeve 48 fixed to the hollow cylindrical member 20 by press-fitting, and the first plunger 21 is in contact with the pressure-sensing piston 41 which is integrally formed with the valve element 16. The hollow cylindrical member 20 has a lower part thereof, as viewed in the figure, expanded such

that annular space is defined between the same and the sleeve 48, with a communication hole 49 being formed through a stepped portion thereof, for communication between the port 19 via which the suction pressure Ps is introduced and a space above the upper surface of the diaphragm 26. Further, the lower end of the solenoid, as viewed in the figure, is provided with a connector 50 to which is connected the connector of the harness. The connector 50 has the adjustment screw 45 screwed therein for adjustment of load of the spring 36, and is formed with a communication hole 51 for communicating the inside of the solenoid with the atmosphere. The other features of this control valve are identical to those of the control valve for a variable displacement compressor, according to the fourth embodiment, except that the valve element 16 has a tapered shape, and hence description of the operation thereof is omitted.

FIG. 9 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to a seventh embodiment of the present invention. In FIG. 9, component elements identical or equivalent to those shown in FIG. 8 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to the seventh embodiment is distinguished from the control valve for a variable

displacement compressor according to the sixth embodiment in which the centering of the first plunger 21 and the disk 43 is performed by the sleeve 48 fixed to the hollow cylindrical member 20, in that the centering is performed by another method. That is, the first plunger 21 is centered by being fitted on the pressure-sensing piston 41 integrally formed with the valve element 16, and the disk 43 is centered by having a convex portion formed on an end face thereof toward the diaphragm 26 fitted in a concave portion formed in the center of the diaphragm 26 and the second plunger 32. It should be noted that the same effects can be obtained by providing a concave portion in the disk 43 and providing a convex portion on the diaphragm 26 and the second plunger 32. The other features of the construction of this control valve are the same as those of the control valve for a variable displacement compressor, according to the sixth embodiment shown in FIG. 8, and therefore, description of the operation thereof is omitted.

FIG. 10 is a central longitudinal cross-sectional view showing the construction of a control valve for a variable displacement compressor, according to an eighth embodiment of the present invention. In FIG. 10, component elements identical or equivalent to those shown in FIGS. 7 and 8 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement

compressor, according to the eighth embodiment is distinguished from the control valve for a variable displacement compressor, according to the fifth embodiment shown in FIG. 7 in that the shape of the first plunger 21 is changed such that it is promptly brought into contact with the diaphragm 26.

That is, the first plunger 21 is axially movably held by two C-shaped guides 22 provided therearound in sliding contact with the inner wall of the hollow cylindrical member 20 with a predetermined distance maintained from the surface of the inner wall. Therefore, the first plunger 21 is held by the hollow cylindrical member 20 with a relatively large clearance provided between the first plunger 21 and the hollow cylindrical member 20. An end face of the first plunger 21 opposed to the diaphragm 26 is not flat but configured such that a center and its neighborhood thereof is formed as a flat surface and a surrounding portion is gently tapered, or such that the cross-section of the end face has a shape of an arc having a large radius.

If the guide 22 is made of a material, e.g. polytetrafluoroethylene, having a characteristic of expanding and contracting depending on temperature or the type of refrigerant, when the solenoid is energized to cause the first plunger 21 and the second plunger 32 to attract each other, the guide 22 sometimes causes the first plunger 21 to be inclined and then bring the same

into contact with the diaphragm 26. In this case, the end face of the first plunger 21 opposed to the diaphragm 26 is brought into abutment the diaphragm via its tapered portion, and therefore it is possible to cause the valve element 16 to promptly close the valve section. This prevents occurrence of a two-step operation occurring in the case of the end face of the first plunger 21 opposed to the diaphragm being flat, i.e. a two-step operation in which a peripheral portion of the flat end face of the first plunger 21 is brought into contact with the diaphragm 26 by the attractive force, and then the flat end face of the first plunger 21 is brought into contact with the diaphragm 26. This makes it possible to promptly close the valve element 16, and close the valve element 16 with accuracy since the phenomenon of the first plunger 21 being stopped at a first step of the two-step operation does not occur.

It should be noted that this control valve for a variable displacement compressor has the same construction as that of the control valve for a variable displacement compressor, according to the fifth embodiment shown in FIG. 7, except that the end face of the first plunger 21 opposed to the diaphragm 26 has a tapered shape, and the first plunger 21 is supported by the two guides 22, and therefore, description of the operation thereof is omitted.

FIG. 11 is a central longitudinal cross-sectional view showing the construction of a control valve for a

variable displacement compressor, according to a ninth embodiment of the present invention. In FIG. 11, component elements identical or equivalent to those shown in FIG. 10 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to the ninth embodiment is distinguished from the control valve for a variable displacement compressor, according to the eighth embodiment shown in FIG. 10 in that a bellows is used for the pressure-sensing member for sensing the suction pressure Ps.

That is, the bellows 52 is disposed between the first plunger 21 and the second plunger 32. The bellows 52 has its flange portion radially extending from an upper end face thereof as viewed in the figure, sandwiched between the hollow cylindrical member 20 and the casing 27 of the solenoid, and sealed by the gasket 28. The lower end face of the bellows 52 as viewed in the figure is closed, and in contact with the second plunger 32. The first plunger 21 has a columnar member 53 formed integrally therewith at a lower portion thereof as viewed in the figure, and the columnar member 53 is positioned in a hollow space of the bellows 52. When the solenoid is not energized, and the first plunger 21 is urged by the spring 24 in the upward direction as viewed in the figure, the columnar member 53 of the first plunger 21 is spaced from

the bellows 52.

It should be noted that this control valve for a variable displacement compressor has the same construction as that of the control valve for a variable displacement compressor, according to the eighth embodiment shown in FIG. 10, except that the bellows 52 is used for the pressure-sensing member. Therefore, the operation of the control valve according to the present embodiment is the same as that of the control valve according to the eight embodiment, and hence description of the operation thereof is omitted.

FIG. 12 is a partial enlarged central longitudinal cross-sectional view for explaining the construction of a valve section of a control valve for a variable displacement compressor, according to a tenth embodiment of the present invention. In FIG. 12, component elements identical or equivalent to those shown in FIG. 11 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to the tenth embodiment is configured such that even when the suction pressure Ps is in any condition, making the receiving pressure unbalanced with the discharge pressure Pd received at the valve section, it is possible to promptly fully open the valve.

That is, in the control valves for a variable displacement compressor shown in FIGS. 4, 7 to 11, the

ports of the valve section are arranged from the solenoid side in the order of the respective ones for the suction pressure Ps, the discharge pressure Pd, and the pressure Pc for the crank chamber, so as to prevent the discharge pressure Pd, which is highest in pressure, from affecting the control of valve element 16. This is achieved by making the inner diameter A of the valve hole equal to the outer diameter B of the pressure-sensing piston 41, which causes the force of the discharge pressure Pd acting on the valve element 16 in the upward direction as viewed in the figure to be cancelled out by the force of the same acting on the pressure-sensing piston 41 in the downward direction as viewed in the figure. In the construction of canceling out the discharge pressure Pd, the valve element 16 controls the valve section by the differential pressure (Pc - Ps) between the pressure Pc for the crank chamber and the suction pressure Ps.

However, the differential pressure (Pc - Ps) between the pressure Pc acting on the valve element 16 and the suction pressure Ps acting on the pressure-sensing piston 41 imposes load on the valve element 16 and the pressure-sensing piston 41 in the self-closing direction since the pressure Pc is higher than the suction pressure Ps. Therefore, when the feed of current to the solenoid is stopped to fully open the valve section, the spring 24 urging the first plunger 21 in the valve-opening direction presses the pressure-sensing piston 41 to cause the valve

element 16 to be made separate from the valve seat 15. However, as the differential pressure (Pc - Ps) increases, the load in the self-closing direction also increases, which makes the valve section difficult to open, and in some cases, the phenomenon of incapable of opening the valve section occurs. Particularly, in the case of variable displacement compressors that dispense with an electromagnetic clutch, no matter the suction pressure Ps may be in what pressure condition, when the power supply to the solenoid is stopped, it is necessary to forcibly fully open the control valve to minimize the discharge capacity of the compressor.

To this end, in this control valve for a variable displacement compressor, the inner diameter A of the valve hole is made e.g. approximately 3 % larger than the outer diameter B of the pressure-sensing piston 41, to make the pressure-receiving area of the valve element 16 larger than the pressure-sensing area of the pressure-sensing piston 41, whereby the pressure-receiving balance related to the discharge pressure Pd is thrown off in the valve-opening direction. This makes the load in the self-closing direction smaller even when the differential pressure (Pc - Ps) increases, so that it is possible to positively fully open the valve section by the urging force of the spring 24 when the power supply to the solenoid is turned off.

FIG. 13 is a central longitudinal cross-sectional

view showing the construction of a control valve for a variable displacement compressor, according to an eleventh embodiment of the present invention. In FIG. 13, component elements identical or equivalent to those shown in FIGS. 5 and 10 are designated by the same reference numerals, and detailed description thereof is omitted.

The control valve for a variable displacement compressor, according to the eleventh embodiment, is configured such that in addition to control provided by the control valve for a variable displacement compressor, according to the eighth embodiment shown in FIG. 10, on the flow rate of refrigerant introduced into the crank chamber while canceling out the discharge pressure Pd of refrigerant introduced into the crank chamber, this control valve provides control also on the flow rate of refrigerant having pressure Pc allowed to escape from the crank chamber into the suction chamber.

That is, the body 11 is provided with a port 14a for guiding refrigerant out into the crank chamber and a port 14b for introducing refrigerant from the crank chamber, and this port 14b communicates with a space accommodating the first plunger 21 via a refrigerant passage 54 coaxial with the pressure-sensing piston 41. The solenoid side end of the pressure-sensing piston 41 has a valve element 55 integrally formed therewith, and the valve element 55 has an end face thereof in contact with the first plunger 21. The valve element 55 has a valve element structure of a

spool valve. When the valve element 16 is lifted off the valve seat 15, the valve element 55 closes the refrigerant passage 54 to block off the flow of refrigerant from the crank chamber to the suction chamber, whereas when the valve element 16 is seated on the valve seat 15, the valve element 55 opens the refrigerant passage 54 to allow refrigerant in the crank chamber to escape into the suction chamber via the port 19. This makes it possible to promptly increase or decrease the pressure Pc in the crank chamber, whereby the variable displacement compressor can be promptly shifted to the minimum capacity operation or the maximum capacity operation.

As describe above, according to the present invention, the plunger of the solenoid is divided in two, with the pressure-sensing member being disposed between them, for sensing suction pressure, and one of the divisional plungers performs valve opening control of the valve section for controlling the pressure in the crank chamber. This makes it possible to construct components ranging from the valve section to a portion where the pressure-sensing member is disposed, including one of the plungers which controls the valve lift of the valve section, as components to which pressure is applied, and part of the solenoid exclusive of one the plungers which controls the valve lift of the valve section can be constructed as part open to the atmospheric pressure without being accommodated in the pressure chamber.

Further, when the solenoid is not energized, the pressure-sensing member is moved away from one of the plungers which controls the valve lift of the valve section, so that the displacement of the pressure-sensing member is not transmitted to the valve section, and at the same time, the valve section is held in a fully open state. This makes it possible to control the variable displacement compressor to the minimum capacity without using an electromagnetic clutch.

The foregoing is considered as illustrative only of the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and applications shown and described, and accordingly, all suitable modifications and equivalents may be regarded as falling within the scope of the invention in the appended claims and their equivalents.